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(54) Device and method for fixing and glossing toner images

(57) The device for fixing an unfixed toner particle image (42) on a substrate (40) comprises a belt (12) in face-to-face contact with a reaction surface such as a further belt (14) to form an extended contact zone (Z1) therebetween, to define a substrate path extending through the contact zone (Z1) from an entrance (16) to an exit (18). Heating means (20) heat the belt (12) adjacent the entrance (16) to a temperature above the softening point T_g of the toner. Cooling means (24) forcibly cool the belt (12) intermediate the entrance (16) and the exit (18) to a temperature below the softening point T_g of the toner. Means (32, 34) are provided for applying pressure between the belts (12, 14) intermediate the entrance and exit. Second heating means (28) heat the belt (12) adjacent the exit (18) to a temperature above the softening point T_g of said toner. Thereby un-fixed toner images formed on the substrate can be fixed thereto and provided with a desirable level of gloss in one single device.

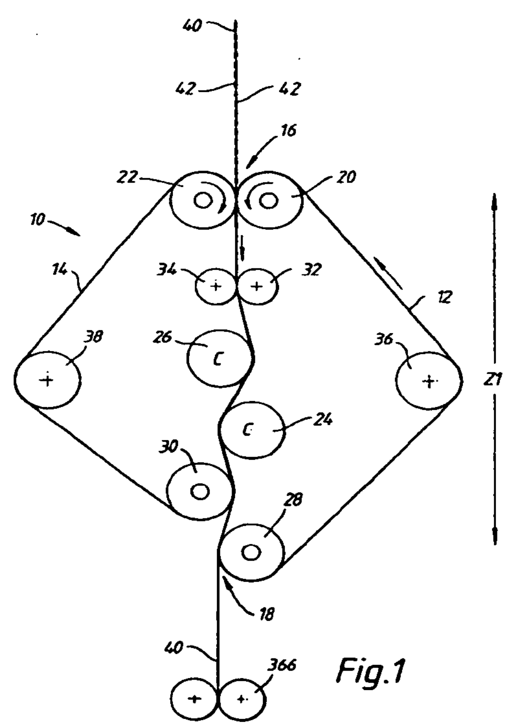

Fig.1

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Description

Field of the invention

This invention is concerned with the fixing of toner images on a substrate in an electrostatographic printer or copier. More particularly, it is concerned with the fixing of powder toner images obtained via electrophotographic, electrographic, ionographic or magnetic recording processes in which an electrostatic or magnetographic latent image is rendered visible by the deposition of a suitable toner composition on the latent image.

Background to the invention

In present day copying machines or electronic printer devices, the fixing or permanent adherence of a toner image on a substrate in the form of a sheet is often carried out with a so-called hot roller or nip-roller fixing system. This image-fixing device comprises a pair of rollers through the nip of which a sheet carrying a toner image is fed. The surface of the roller contacting the toner image is heated above the softening temperature of the toner resin, which becomes tacky or molten and forms a permanent bond with the surface of the sheet. The roller, contacting the toner image, is provided with a coating having abhesive (i.e. non-adhesive) properties versus the toner image. In order to increase the non-adhesive characteristics of the roller surface, use is often made of silicone oil. The rollers forming the image-fixing unit are pressed against each other. The roller contacting the backside of the sheet is generally covered with a silicone elastomer, capable of resisting the heat generated by the image-fixing roller.

Problems arise with hot roller image-fixing devices. In particular, in heavy duty printers where long periods between servicing are usual, it is difficult to maintain a constant image-fixing quality and a long roller lifetime.

A technique known as "flash-fixing" is also known in which a short intense burst of radiant energy is applied to the substrate carrying the toner image to be fixed. The wavelength of the radiant energy is chosen to be absorbed by the toner. Such a technique is unsuitable for multi-colour images, where toners of different composition are carried on the substrate, said toners having different absorption characteristics in the visible spectrum.

A number of constructions of image fixing devices using infra-red radiant fixing have been proposed in the art. United States patent US 3449546 (Dhoble / Xerox Corporation) describes a xerographic fusing apparatus, which is capable of heating toner powder to its softening point without damaging the paper support material, wherein the paper acts as a heat source to aid in the fusing process. United States patent US 5526108 (Billet et al / Xeikon NV) describes a radiant fixing device comprising at least one radiant source, the peak energy output wavelength of which lies in the non-visible part of the spectrum.

Infra-red fixing devices however cause a loss of moisture from the substrate, as a result of the high temperature to which the substrate is heated, i.e. the substrate becomes too dry. This loss of moisture can result in deformation of the substrate and the low moisture level can result in the generation and retention of electrostatic charges on the substrate, both of which effects can produce problems in subsequent handling of the substrate.

A number of proposals have been made for fixing toner images by the use of a belt.

In United States patent US 3948215 (Namiki / Ricoh Co., Ltd) a toner image on a support sheet is fused either by disposing the sheet in with a heating surface. After the toner particles are fused, the sheet is cooled while maintaining its image bearing side in contact with the surface previously used for heating, so that the particles solidify and the toner image is stiffened. Pressure may be applied to the support sheet as it contacts the heating surface.

US 5483331 (Wayman et al. / Xerox Corporation) describes a transfer and fusing belt arrangement in which three fuser rollers cooperate with a pressure roller to form an extended fusing zone through which an electrically resistive substrate carrying toner images passes, with the toner images contacting the fusing belt. Electrical power is applied to the three fuser rollers so that only the portions between these rollers are heated.

Other proposals concerning image fixing include the following. European patent application EP 295901 (Canon KK) describes an image fixing device for fixing an unfixed image on an image carrying member, which includes a sheet member movable together with the unfixed image carrying member in contact with the unfixed image carried thereon, and a heat generating element contacted to such a side of the sheet member as is opposite to a side thereof contactable to the unfixed image, the heat generating element being fixed in use. United States patent US 4780742 (Canon KK) describes how a printed copy sheet having an image is coated with a thin sheet at the image bearing side. The copy is then pressed together with the thin sheet, and simultaneously heated so as to soften or fuse at least the surface of the image. then, the sheet is peeled off the image after the image is cooled sufficiently.

Due to the fact that dry toner images have a high thickness (sometimes more than 10 µm), the appearance of such images is sometimes unnatural and non-uniform and these images usually have a non-uniform colour saturation. While this appearance is acceptable for many applications, it is sometimes desired to provide an image having a different appearance or finish. By the term "finish" in the context of the present invention, we mean either a surface characteristic which is glossy, i.e. highly reflective, and/or which provides high saturation of colours, this usually being achieved by reducing the scattering of light from the surface of the printed article,

or both such characteristics. For example, a glossy appearance is especially desirable where the receiving material itself has a glossy surface. A higher degree of colour saturation can be very desirable in high quality print work.

It has been proposed to provide glossy images by the use of a toner which incorporates a glossing agent, or by the application of a transparent glossing layer over the toner image. However, these methods are costly in terms of consumables.

In US 5521688 (Moser / Xerox Corporation) it has been proposed to provide glossy images by passing the substrate carrying the toner images through an oven heater to fix the images and then through a pair of glossing rollers operating at approximately the same temperature as the oven.

United States patent US 5319429 (Fukuchi et al. / Konica Corporation) describes a colour printer having a fixer for fixing a toner image on a recording sheet, which includes an endless polyimide heat belt which is supported by a heat roller and a separation roller, and an endless conveyance belt which is supported by a pressure roller and another separation roller. The endless heat belt and the conveyance belt are pressed together over part of their length, so that a nip region is created between the first pair of rollers and the second pair. The belts have glossy surfaces.

Other proposals concerning the glossing of images include the following. United States patent US 5099288 (Lexmark International) proposes that a document, carrying thermoplastic toner to be fixed, is held in the nip of belts where it is moved under a heater. The toner is in contact with the longer of the two belts. When a slightly rough image is desired, the document is removed while the toner is still mobile and has some affinity for the belt. When a very smooth image is desired, the document is removed after the toner is cooled. United States patent US 5258256 (Eastman Kodak Company) describes a method of fusing a toner image to provide desirable levels of gloss. The toner particles have a loss tangent value of 1.2 or more upon fusing with combined heat and pressure. The unfused toner image is subjected to fusing in three distinct zones; a fusing zone where it is contacted with a fusing member, a cooling zone where contact with the fusing member is maintained and the image is cooled; and a release zone where the image is released from the fusing member at a temperature where no toner image offset occurs.

It would be desirable to use one and the same device to fix the toner images and to provide them with the desired gloss. However, contact-less fixing devices are unable to provide a uniform glossing effect, while we have found that the use of known heated rollers or heated belt fixing devices suffer from toner offset problems and do not provide sufficient control over the gloss and colour saturation of the images. In particular such known devices exhibit limited process parameters, with a narrow window of optimum performance.

OBJECTS OF THE INVENTION

It is an object of the present invention to provide a device and method whereby un-fixed toner images can be fixed to a substrate and provided with a desirable level of gloss in one single device, while widening the range of operating conditions without risk of offset occurring.

SUMMARY OF THE INVENTION

We have found that this, any other useful objectives can be achieved by the use of a belt or other endless surface fuser having a contact zone through which the substrate passes, the endless surface being cooled within the contact zone, by applying pressure within the contact zone and/or by heating the belt adjacent the exit of the contact zone to a temperature above the softening point T_g of the toner.

Thus, according to one aspect of the invention, there is provided a device for fixing an unfixed toner particle image on a substrate, comprising an endless surface, a reaction surface in face-to-face contact with the endless surface to form a contact zone therebetween, extending continuously from an entrance to an exit, means for feeding a substrate through the contact zone from the entrance to the exit, heating means for heating the endless surface adjacent the entrance to a temperature above the softening point T_g of the toner, and cooling means for forcibly cooling the endless surface intermediate the entrance and the exit to a temperature below the softening point T_g of the toner, characterised by means for applying pressure between the endless surface and the reaction surface intermediate the entrance and exit.

The first aspect of the invention also provides a method of fixing an unfixed toner particle image on a substrate, comprising feeding the substrate through a contact zone which extends continuously from an entrance to an exit thereof and is defined by an endless surface and a reaction surface in face-to-face pressure contact with the endless surface, heating the endless surface adjacent the entrance to a temperature above the softening point T_g of the toner, and forcibly cooling the endless surface intermediate the entrance and the exit to a temperature below the softening point T_g of the toner characterised by applying pressure between the endless surface and the reaction surface intermediate the entrance and exit.

While not wishing to be bound by theory, we believe that, where toner images are fixed on a substrate by means of a heated surface such as a roller or heated belt, there is a risk of molten toner becoming transferred to the heated surface as the substrate separates therefrom, to be subsequently deposited on a following section of substrate, resulting in the phenomenon of "ghost images". Even if the characteristics of the heated surface are so chosen as to reduce the risk of such "hot-off-

set", the separation of the heated surface from the substrate tends to distort the toner particles into a somewhat non-flat shape, leading to low gloss and colour saturation. Forcibly cooling the substrate on the other hand, while pressure is applied thereto, tends to flatten the toner particles, leading to an increase in colour saturation or alternatively enabling the quantity of toner used during printing to be reduced by, for example, 20% to 30%. Thus, it is essential according to the invention to cool the endless surface to a temperature below the softening point T_g of the toner while the endless surface is in pressure contact with the reaction surface. There is therefore a temperature gradient within the contact zone, from a temperature above the softening point T_g of the toner adjacent the entrance of the contact zone to a temperature below the softening point T_g of the toner before the exit from the zone.

The endless surface will generally be the surface of a belt, although it is also possible for the endless surface to be constituted by the surface of a drum. As used in the following general description, the term "belt" is intended to embrace other forms of endless surface, such as a drum, except where the context demands otherwise.

The heating means may comprise a heating surface in contact with the belt, such as a roller, or a heated stationary body over which the belt passes. Heating may be achieved, for example, by passing a heating fluid (e.g. steam or hot oil) at an elevated temperature through the roller or stationary body, or by the provision of radiant heating means positioned within the roller or stationary body. It is also possible to use radiant heating means for directly heating the belt, and this may be especially beneficial where the belt is formed primarily of heat non-conductive material. Generally, the belt will be heated from the side thereof opposite to its contact with the reaction surface and the substrate. Generally, the belt contacts the substrate with a dry surface, i.e. there is no need to apply a liquid release agent to the belt surface.

According to a second aspect of the invention, there is provided a device for fixing an unfixed toner particle image on a substrate, comprising an endless surface, a reaction surface in face-to-face contact with the endless surface to form a contact zone therebetween, extending continuously from an entrance to an exit, means for feeding a substrate through the contact zone from the entrance to the exit, heating means for heating the endless surface adjacent the entrance to a temperature above the softening point T_g of the toner, and cooling means for forcibly cooling the endless surface intermediate the entrance and the exit to a temperature below the softening point T_g of the toner, characterised by second heating means provided for heating the belt adjacent the exit to a temperature above the softening point T_g of the toner.

The second aspect of the invention also provides a method of fixing an unfixed toner particle image on a substrate, comprising feeding the substrate through a contact zone which extends continuously from an entrance to an exit thereof and is defined by an endless surface and a reaction surface in face-to-face pressure contact with the endless surface, heating the endless surface adjacent the entrance to a temperature above the softening point T_g of the toner, and forcibly cooling the endless surface intermediate the entrance and the exit to a temperature below the softening point T_g of the toner characterised by heating the endless surface adjacent the exit to a temperature above the softening point T_g of the toner.

The advantage of this second heating is to raise the temperature of the flattened surface of the toner, thereby lowering its surface energy. This eases the release of the toner from the belt, without raising the temperature of the bulk of the toner so much that the toner loses its flatness as it separates from the belt or even breaks down leaving toner deposited on the belt. The second heating means may be constructed in a similar manner to the heating means at the entrance to the contact zone, for example as a second heated roller over which the belt passes. Where second heating means in the form of a second heated roller is provided adjacent the exit of the contact zone, it is preferable to arrange the geometry such that the belt wraps partially around the second heated roller within the contact zone, to enhance the heating effect thereof.

Preferably both aspects of the invention are used together to gain maximum advantage from the invention.

The cooling means may comprise a cooling surface in contact with the belt, such as a cooling roller over which the belt passes. Cooling may be achieved, for example, by passing a cooling fluid (e.g. water at room temperature or reduced temperature) through the roller or stationary body. It is also possible to direct cold or cooled air directly at the belt. Generally, the belt will be cooled from the side thereof opposite to its contact with the reaction surface and the substrate.

The heat extracted from the belt by the cooling means may be used to pre-heat the belt on its return run, in advance of the heating which takes place at the entrance to the contact zone. Thus, the cooling means may be constituted by the cold region of a heat pump, the hot region of which is in contact with the belt on its return run. Alternatively, heat extracted from the belt by the cooling means may be used to pre-heat the substrate.

The belt may comprise a heat conductive backing carrying a coating of non-adhesive material, preferably a silicone rubber. In any event, the belt should have a low thermal capacity, to ensure the rapid heating and cooling thereof. Such rapid temperature changes enable the apparatus to be smaller in size than would otherwise be necessary. The belt should also be formed primarily of a heat conductive material, if heating from the "back-side" thereof is to be used. A heat-conductive

belt has the advantage of distributing a more even temperature, as "hot spots" are avoided. The belt, or at least the coating carried thereon, should be seamless, especially if substrates in web-form are to be used. The belt is preferably impermeable. The reaction surface is also preferably impermeable. The use of an impermeable belt and reaction surface leads to a particular advantage of the present invention. Although the substrate temperature rises in the contact zone, even to above 100°C, any moisture in the substrate cannot escape and condenses on the belt to be returned to the substrate by the second heating means. The disadvantages of open radiant fixing referred to above, resulting from the substrate becoming too dry, are therefore avoided.

The reaction surface may be constituted by a further belt. In this embodiment, further heating means may be provided for heating the further belt adjacent the entrance to a temperature above the softening point T_g of the toner, and further cooling means may be provided for forcibly cooling the further belt intermediate the entrance and the exit to a temperature below the softening point T_g of the toner. Alternatively, the reaction surface may be constituted by a surface of a stationary body, which may include means for cooling the stationary body.

The contact zone extends from the initial point of contact between the belt and its reaction surface to the point of separation between the belt and its reaction surface. It is important to maintain contact within the contact zone, although the pressure need not be constant throughout the zone. The pressure may be generated by virtue of the geometry of the belt and its reaction surface, but it is helpful to provide a pair of intermediate pressure rollers located one on either side of the extended contact zone, upstream of the cooling means. The pressure which is applied intermediate the entrance and exit of the contact zone is preferably applied at the same region as, or immediately before, the region of application of the forced cooling. It is also preferred to apply pressure between the belt and the reaction surface adjacent the entrance to the contact zone. Thus, in the contact zone at least two pressure points are realised, one adjacent the entrance and the other intermediate the entrance and the exit. We have found that an average contact pressure at the pressure points of between 2 to 20 N/cm^2, such as from 5 to 10 N/cm^2 is preferred, depending on the absorbency of the substrate, the temperature and the viscosity of the toner at that temperature.

Where the cooling means and the further cooling means are both constituted by cooling rollers, these cooling rollers should be so positioned as to ensure more than tangential contact between each cooling roller and its associated belt. By ensuring that each belt partially wraps around its associated cooling roller, the forcible cooling effect is thereby obtained.

The unfixed toner particle image which is to be fixed to the substrate may already be present on the substrate, or it may be carried on the endless surface to be transferred to the substrate in the contact zone.

Where a toner particle image is carried on both faces of the substrate (i.e. a "duplex" substrate), the reaction surface is preferably constituted by a further belt which is also heated adjacent the entrance to a temperature above the softening point T_g of the toner, and cooled intermediate the entrance and the exit to a temperature below the softening point T_g of the toner.

Alternatively, the toner particle image may be carried on one face only of the substrate (i.e. a "simplex" substrate). For example, the substrate may comprise adhesive labels carried on a plastics material backing sheet. For such "simplex" substrates, the reaction surface may be constituted by either a further belt or by a stationary body. Where a further belt is used as the reaction surface for "simplex" substrates, it need not be heated at all. Indeed, forcibly cooling the further belt, even from the entrance of the contact zone, helps to avoid distortion of the substrate.

The substrate may be in the form of a web, but the invention is equally applicable to substrates in sheet form, the device then being provided with suitable sheet feeding means. The geometry of the device may be such as to define a substantially straight path for the substrate. This can be of advantage for heavier, especially thicker or less flexible, substrates.

The belt, and the further belt where present, may be driven directly, for example by applying drive to a heating roller at the entrance of the contact zone, to a second heating roller at the exit of the contact zone or to an intermediate pressure roller. It is important to arrange for the belt to be driven in synchronism with movement of the substrate, and with the further belt where present, to prevent slippage which may distort the toner image. Alternatively, where the substrate is in the form of a web, the belt, and the further belt where present, may be driven by movement of the web itself, means being provided to compensate for the torque resistance of the belt(s). This arrangement ensures that the substrate web and the belt(s) move in synchronism.

The belt may return from the exit of the contact zone to the entrance thereof via an adjustable tensioning and alignment roller. Where an intermediate pressure roller is in contact with the belt within the contact zone, this intermediate pressure roller may be in heat exchange relationship with the alignment roller, for example by way of a heat exchange fluid passing through hollow interiors of both rollers. The energy requirements of the device can thereby be reduced.

The device according to the invention may be part of a printer, advantageously an electrostatographic printer, having at least one imaging station, where a latent image is formed upon a rotatable endless surface member such as an electrostatically chargeable photoconductive drum or belt and an array of image-wise modulated light-emitting diodes is used as an exposure source. The latent image is then developed at a toner

development station to form a toner image on the surface member. The toner image is transferred at a toner transfer station from the surface member onto a moving substrate, or onto a moving transfer member for later transfer to a substrate. The printer may also be equipped with cutting means in order to cut the printed web into sheets. The cutting means is preferably positioned downstream of the fixing device.

The development station uses a developer which contains toner particles containing a mixture of a resin, a dye or pigment of the appropriate colour and normally a charge-controlling compound giving triboelectric charge to the toner. In dual-component developers which are normally used, carrier particles are also present for charging the toner particles by frictional contact therewith. The carrier particles may be made of a magnetizable material, such as iron or iron oxide. Developing technologies other than magnetic brush development, such as mono-component developers, can be used.

Dry-development toners essentially comprise a thermoplastic binder consisting of a thermoplastic resin or mixture of resins including colouring matter, e.g. carbon black or colouring material such as finely dispersed pigments or dyes.

The mean diameter of dry toner particles for use in magnetic brush development is conventionally about 10 µm (ref. "Principles of Non Impact Printing" by Jerome L. Johnson - Palatino Press Irvine CA, 92715 U.S.A. (1986), p. 64-85). For high resolution development, the mean diameter may be from 1 to 5 µm (see e.g. British patent specification GB-A-2180948 and International patent specification WO-A-91/00548).

The toner particles contain in the resinous binder one or more colorants (dissolved dye or dispersed pigment) which may be white or black or has a colour of the visible spectrum, not excluding however the presence of infra-red or ultra-violet absorbing substances.

The thermoplastic resinous binder may be formed of polyester, polyethylene, polystyrene and copolymers thereof, e.g. styrene-acrylic resin, styrene-butadiene resin, acrylate and methacrylate resins, polyvinyl chloride resin, vinyl acetate resin, copoly(vinyl chloride-vinyl acetate) resin, copoly(vinyl chloride-vinyl acetate-maleic acid) resin, vinyl butyral resins, polyvinyl alcohol resins, polyurethane resins, polyimide resins, polyamide resins and polyester resins. Polyester resins are preferred for providing high gloss and improved abrasion resistance. Such resins usually have a glass transition point Tg of more than 54°C with a melt viscosity of at least 50 Pas up to no more than 1500 Pas. The presence of other ingredients in the toner particles, such as the colorant, usually have no significant effect upon the glass transition temperature. The volume resistivity of the resins is preferably at least 10^{13} Ω-cm.

Suitable toner compositions are described in European patent applications EP-A-601235, and EP-A-628883 and International patent applications WO 94/27192, 94/27191 and 94/29770 (all Agfa-Gevaert NV). The softening points of most common toner compositions are similar at about 60°C. The typical fixing temperature is therefore about 120°C, depending *inter alia* on the nature of the substrate and the pressure applied. Where the substrate carries a number of different toners, as for example in the case of multi-colour images, the belt should raise the temperature to above the lowest softening temperature of the toners present, most preferably above the highest softening temperature of the toners present.

We prefer to use toners having a composition comprising a thermoplastic binder and from 10% to 50% by weight, based on the weight of the toner composition, of a pigment. We also prefer that the toner composition in powder form has a weight average particle size of between 0.5 µm and 5 µm, preferably between 1 µm and 4 µm. The use of toner compositions having a higher level of pigment therein enables images with a higher density to be printed. Alternatively, for the same image density, smaller toner particles can then be used. The use of smaller toner particles has the advantage that the height of the toner image above the surface of the substrate is lower. The advantages of a lower toner image height include (a) irregularities in the surface of the substrate have less of an effect upon the gloss of the image, (b) the total usage of toner is reduced - this is important because the cost of the toner may be significant in the total cost of the printed product, (c) the tendency of the printed page to curl is reduced, (d) the stacking of printed pages, for example in the preparation of a book, is more even, and (e) there is a flatter feel to the printed page, a characteristic which is of advantage to some users.

Where the unfixed toner particle image is to be transferred to the substrate in the contact zone, i.e. where the endless surface which defines the contact zone carries the unfixed toner particle image, the endless surface is preferably heated adjacent the entrance to the contact zone to a temperature above the fluid temperature of the toner. In particular, the surface of the toner image should contact the substrate at a temperature above the fluid temperature of the toner, so as to ensure mixing of the toner particles of different colours, complete transfer of the mixed multiple toner image to the substrate and the fixing of the image on the substrate. The fluid temperature is the temperature at which the viscosity of the toner falls below 50 Pa s, such as from 10 Pa s to 40 Pa s. This temperature to which the multiple toner image is heated is above the glass transition temperature of the toner but below the degradation temperature thereof, that is below the temperature at which irreversible changes occur in the toner composition leading to a significant change in its spectral properties. The fluid temperature is typically above 150°C, even above 200°C, depending upon the composition of the toner. Viscosity is typically measured by the use of a cup viscometer (Ford cup, Shell cup or Zahn cup).

ASTM D-1200 is an accepted standard for the measurement of viscosities of printing inks. Laray and Churchill falling rod viscometers may also be used.

Another aspect of the present invention is a method for the transfer of a toner image in powder form from a transfer member to the substrate, comprising:

(1) heating the toner image to a temperature sufficient to reduce the viscosity thereof to less than 50 Pa s;
(2) bringing the transfer member carrying the toner image into contact with the substrate;
(3) forcibly cooling the transfer member to a temperature below the glass transition temperature T_g of the toner while the transfer member remains in contact with the substrate; and
(4) thereafter separating the transfer member from the substrate.

The toner image may be heated to a temperature of more than the glass transition temperature T_g, e.g. more than 200°C, but below the degradation temperature of the toner.

Where the toner image is to be transferred to a substrate in a contact zone defined by a reaction surface in face-to-face contact pressure with the transfer member, as described above, and duplex printing is desired, the reaction surface is preferably constituted by a further transfer member which is also heated adjacent the entrance to a temperature above the glass transition temperature T_g of the toner, and cooled intermediate the entrance and the exit to a temperature below the glass transition temperature T_g of the toner.

The printer may be a colour printer, containing a plurality of imaging stations each associated with a development and transfer station and the image-fixing station is located downstream of the last toner transfer station before cutting the printed web. In one embodiment of such a colour printer, the development stations contain respectively cyan, magenta, yellow and optionally black toner particles.

The web of substrate may be fed through the printer from a roll. If desired, the substrate may be conditioned (i.e. its moisture content adjusted to an optimum level for printing), prior to entering the printer.

The printer according to the invention may be a duplex colour printer which includes two sets of imaging, development and transfer stations, one set at each side of the web. The invention is however equally applicable for use with a printer intended for simplex (i.e. one-sided) printing.

The device according to the invention may also be part of an electrostatic copier, working on similar principles to those described above in connection with electrostatic printers. In copiers however, it is common to expose the rotatable endless surface member by optical means, directly from the original image to be copied.

In a particular embodiment, this invention also relates to a printer, in particular to a single pass, electrostatographic printer, and to a method of single-pass electrostatographic printing.

Thus, according to a further aspect of the invention, there is provided a single pass, electrostatographic printer comprising:

- a transfer member;
- drive means for moving the transfer member along a continuous path;
- deposition means for depositing a toner image in powder form on the transfer member to form an unfixed toner particle image thereon; and
- a reaction surface in face-to-face pressure contact with the transfer member to form a contact zone therebetween, extending continuously from an entrance to an exit,
- means for feeding a substrate through the contact zone from the entrance to the exit, whereby the toner image is transferred to the substrate;
- heating means for heating the transfer member adjacent the entrance to a temperature above the softening point T_g of the toner, and
- cooling means for forcibly cooling the transfer member intermediate the entrance and the exit to a temperature below the softening point T_g of the toner.

The invention also provides a method of single pass, electrostatographic printing comprising:

- moving a transfer member along a continuous path;
- depositing a toner image in powder form onto the moving transfer member to form an unfixed toner particle image thereon;
- feeding substrate through a contact zone which extends continuously from an entrance to an exit thereof and is defined by the moving transfer member carrying the unfixed toner particle image and a reaction surface in face-to-face pressure contact with the moving transfer member whereby the toner image is transferred to the substrate;
- heating the transfer member adjacent the entrance to a temperature sufficient to reduce the viscosity thereof to less than 50 Pa s (such as 10 to 40 Pa s); and
- forcibly cooling the transfer member intermediate the entrance and the exit to a temperature below the softening point T_g of the toner.

The transfer member plays the role of transferring the multiple toner image to the substrate. It is not necessary therefore that the transfer member has a photoconductive surface. Indeed, the need to heat and cool the transfer member in the apparatus according to the invention means that the use of conventional photoconductor materials is to be avoided, since the photoconductive properties of such materials are sensitive to temperature changes.

While not wishing to be bound by theory, it is our understanding that it is generally preferred to transfer toner images from a material of relatively low surface energy to one of relatively high surface energy. This reduces the possibility of toner particles shearing during transfer which reduces the efficiency of the transfer process and leaves residual toner on the donor surface. Ideally therefore, the surface energy of the donor surface should be lower than that of the receiving surface. This can be achieved for the transfer of the image from the transfer member to the substrate, since the surface energy of the substrate, such as paper, is generally more than 45 dyne/cm. The transfer process is more efficient when the donor surface is at a higher temperature than the receiving surface. Thus the present invention requires heating of the toner image on the transfer member so as to maximise the efficiency of the transfer to the substrate.

The transfer member may comprise an outer surface formed of a material having a low surface energy, for example silicone elastomer (surface energy typically 20 dyne/cm), polytetrafluoroethylene, polyfluoralkylene and other fluorinated polymers. The transfer member is preferably in a form having a low mass, so that the surface thereof can be easily heated prior to the transfer of the multiple toner image to the substrate and easily cooled after transfer cooled before the transfer thereto of a further multiple toner image from the primary belt. For this reason, while the transfer member can be in the form of a transfer roller or drum, it is preferably in the form of a transfer belt, for example an endless metal belt of 40 µm thickness coated with 40 µm thickness silicone rubber.

Where the printer is a multi-colour printer, the method will include depositing a plurality of toner images of different colours in powder form in register with each other onto the moving transfer member to form a multiple toner image thereon. A plurality of toner images of different colours may be electrostatically deposited onto the moving transfer member to form a charged multiple toner image thereon. This means that either (Option 1) the multiple toner image is firstly formed on another member and then deposited as such onto the transfer member, or (Option 2) a plurality of toner image deposition devices operate sequentially at different locations along the transfer member path to deposit toner images on the transfer member. In the latter alternative, the operation of the toner image deposition devices is so controlled in relation to each other as to ensure the desired registration of the various different images.

Thus, according to one embodiment of Option 1 of the invention, the transfer member is an intermediate transfer member and the means for forming a multiple toner image on the transfer member comprises:

- a primary transfer member;
- means for guiding the primary transfer member past a set of toner image producing stations whereby a plurality of toner images of different colours are formed on the primary transfer member in register with each other to form the multiple toner image on the primary transfer member, the intermediate transfer member being in contact with the primary transfer member downstream of the image producing stations, whereby the multiple toner image is electrostatically transferred from the primary transfer member to be deposited on the cooled intermediate transfer member. In this embodiment, the primary transfer member is preferably constituted by a primary belt.

The primary belt may have, for example, a toner image carrying surface formed of an electrically non-conductive material. The electrically non-conductive material is preferably selected from polyethylene terephthalate, silicone elastomer, polyimide (such as KAPTON - Trade Mark), and mixtures thereof. The primary belt may consist entirely of this material, or be in the form of a base material coated with such an electrically non-conductive material. The base material of the primary belt may be a metal, such as stainless steel, a polyimide, a polyvinyl fluoride, a polyester, and mixtures thereof. Polyester has the advantage of good mechanical and electrical characteristics and of being less sensitive to humidity.

The transfer of the multiple toner image from the primary belt to the intermediate transfer member is more difficult to achieve if the intermediate transfer member has a relatively low surface energy. While there would therefore be an advantage in heating the primary belt between the last image producing station and its contact with the intermediate transfer member, there is a risk of the temperature becoming too high. This problem can be avoided according to the present invention, by transferring the multiple toner image from the primary belt to be deposited on the intermediate transfer member by electrostatic means or by a combination of electrostatic means and heat. This has an added advantage of reducing the risk of toner-toner shearing at those portions of the image where toner of one colour lies directly over toner of another colour.

Drive to the primary belt is preferably derived from the drive means for the intermediate transfer member, by making use of adherent contact between the primary belt and the intermediate transfer member causing the primary belt and the intermediate transfer member to move in synchronism with each other. Adherent contact between the primary belt and the image producing stations may be used to ensure that the image producing stations move in synchronism with the primary belt. The primary belt preferably passes over a guide roller positioned in opposition to the intermediate transfer member to form a nip or contact region therebetween.

Means for cleaning the primary belt, and optionally also means for cooling the primary belt, are preferably

provided after contact with the intermediate transfer member.

Means for tensioning the primary belt may be provided in order to ensure good registration of the toner images thereon and to improve the quality of transfer of the multiple toner image therefrom to the intermediate transfer member. Means for controlling the transverse position and movement of the primary belt may also be included.

Each toner image producing station may comprise means for forming an electrostatic latent image on a surface, means for developing the electrostatic image to form a toner image on the surface and transfer means for transferring the toner image onto the primary belt. The surface is preferably the photosensitive surface of a drum. The transfer means may comprise a transfer roller located at the face of the primary belt opposite to the drum, or a corona transfer device. When the transfer means is a transfer roller, the primary belt is in contact with the drum over a contact angle of less than 5°, measured at the axis of the drum, e.g. substantially tangential contact. However, when the transfer means is a corona transfer device, the primary belt is preferably in contact with the drum over a contact angle of more than 5° so that adherent contact between the primary belt and the drum enables drive to be reliably transmitted from the primary belt to the drum. The reliability of this transfer is enhanced by tensioning the primary belt.

The use of a transfer belt has other advantages over, for example, the use of a transfer roller. One run or section of the transfer belt may be heated while the other run is cooled. In this manner, the temperature of the transfer belt at its point of contact with the substrate can be higher than its temperature at its point of contact with the primary belt, leading to an improvement in toner transfer and reducing the chances of offset ghost image effects. For the production of glossy images, it is advisable that the surface of the intermediate transfer member be as flat as possible. In particular it is advantageous if the surface roughness R_a is less than 0.2 µm. For the production of matt images, the surface roughness may be higher. The use of a transfer belt in place of a transfer roller as the intermediate transfer member enables the contact area between this member and the primary belt to be greater. This enables the adherent contact therebetween to be improved thereby providing a more reliable transmission of drive from the intermediate transfer member to the primary belt without increase in pressure.

The substrate is preferably in the form of a web. Web cutting means, optionally together with a sheet stacking device may be provided downstream of the intermediate transfer member. Alternatively, the web is not cut into sheets, but wound onto a take-up roller. The web of substrate may be fed through the printer from a roll. If desired, the substrate may be conditioned (i.e. its moisture content adjusted to an optimum level for printing), prior to entering the printer.

The substrate may alternatively be in the form of cut sheets, or other articles of suitable shape. The present invention is particularly of advantage in the printing of substrates of significant thickness and rigidity.

Furthermore, embodiments of the present invention have the advantage, in comparison to those printing devices in which a toner image is electrostatically transferred directly to the substrate, that the electrical condition of the substrate is less critical. There is, for example, no need to condition the substrate to adjust its moisture content to within a specified range, nor to condition the environment of the printer. The range of substrate types which can be used is also increased, to include for example substrates formed of synthetic materials, of flimsy materials or of irregular shape.

Means for heating the substrate are preferably provided in advance of contact with the intermediate transfer member. This may be achieved by the use of heating means selected from infra-red and high-frequency radiant heating means, convection heating means, conduction heating means, such as heated rollers, and other known heating means.

It may be desired to print a toner particle image on both faces of the substrate (i.e. "duplex" printing). The printer according to the invention may be adapted for duplex printing, by comprising:

- electrostatic deposition means for depositing a second such multiple toner image on a second transfer member, the substrate feed means being adapted to feed substrate along a substrate path into contact with the second transfer member, whereby the second multiple toner image is transferred to the opposite face of the substrate; and
- means for heating the second multiple toner image on the second transfer member in advance of the transfer of the second multiple toner image to the substrate; and
- means for cooling the second transfer member following the transfer of the second multiple toner image therefrom to the substrate prior to the deposition of further toner images on the second transfer member.

The second transfer member may be a second intermediate transfer member and the means for forming a second multiple toner image on the second transfer surface may then comprise:

- a second primary transfer member;
- means for guiding the second primary transfer member past a second set of toner image producing stations whereby a second plurality of toner images of different colours are transferred to the second primary transfer member in register with each other to form the second multiple toner image on the second primary transfer member, the second intermediate transfer member being in contact

with the second primary transfer member downstream of the second set of image producing stations.

In this embodiment, the first and second intermediate transfer members may be positioned in opposition to each other to form the contact zone therebetween, through which the substrate path passes. Drive to the second intermediate transfer member may be derived from the first intermediate transfer member or may be derived from a separate drive motor, controlled to drive the second intermediate transfer member in synchronism with the first intermediate transfer member.

It is possible for the primary belt and the intermediate transfer member to be constituted by one and the same member, as described in European patent application EP 775948 (Xeikon NV), thereby forming an embodiment of Option 2 of the invention. The transfer member may be constituted by a belt and there are provided means for guiding the belt past a set of toner image producing stations whereby a plurality of toner images of different colours are transferred to the belt in register with each other to form the multiple toner image on the belt, and the substrate feed means are arranged to feed substrate along a substrate path into contact with the belt.

In order to reduce energy loss to the environment, we prefer that the means for heating the toner image on the transfer member is in heat exchange relationship with the means for cooling the transfer member after transfer. For example, the means for heating the multiple toner image on the transfer member comprises a pre-heating roller and the means for cooling the transfer member comprises a pre-cooling roller, the pre-heating roller and the pre-cooling roller being in heat exchange relationship with each other. This heat exchange relationship can be achieved for example by each of the heating and cooling rollers being hollow rollers through which a heat exchange fluid, such as water, is caused to flow. In this way heat extracted by the cooling roller is transferred to the heating roller and contributes to the heating of the toner image on the transfer member.

In order not to disturb the multiple toner image on the transfer member between the deposition of the image thereon and the transfer of the image to the substrate, we prefer that the surface of the transfer member which carries the image is free of contact with any other member. Thereby, undesirable transfer of the image, or a part thereof, from the transfer member is avoided. Thus, where for example the transfer member is in the form of a belt, rollers or other guide means, contact the belt on the surface thereof opposite to that carrying the image, at least between the deposition of the image and its transfer to the substrate.

The invention will now be described in further detail, purely by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a fixing device according to the invention, for fixing toner images carried on both faces of a substrate in the form of a web;

Figure 2 shows charts plotting pressure and temperature against the position of the substrate in the device according to Figure 1; and

Figure 3 shows an alternative embodiment according to the invention, for fixing toner images carried on one face of a substrate in the form of adhesive labels carried on a plastics material backing web.

Figure 4 shows a single pass, multi-colour duplex electrostatographic printer according to another embodiment of the invention, incorporating a simultaneous fixing and glossing device similar to that shown in Figure 1.

Figures 1 to 3 illustrate the principle of a device for simultaneously fixing a toner image on a substrate and providing the image with the desired gloss, as applied to a substrate already carrying an unfixed toner image.

Referring to Figure 1, the device 10 comprises a first belt 12, and a second belt 14 which constitutes a reaction surface in face-to-face pressure contact with the first belt to form an extended contact zone Z1 therebetween, thereby to define a substrate path extending through the contact zone from an entrance 16 to an exit 18. Each belt is impermeable, comprising a 70 µm metal backing carrying a 30 µm coating of non-adhesive silicone material such as DOW 200 series (ex Dow Corning Corporation).

The first belt 12 passes over, and is in contact with, a hard metal heated roller 20 which directly heats the first belt adjacent the entrance 16 to a temperature above the softening point T_g of the toner. Similarly, the second belt 14 passes over a heated roller 22 which directly heats the second belt 14 adjacent the entrance 16 to a temperature above the softening point T_g of the toner.

Each belt 12, 14 also passes over, and is in contact with, a respective resilient cooling roller 24, 26 which directly cools the respective belt intermediate the entrance and the exit of the contact zone Z1 to a temperature below the softening point T_g of the toner. The cooling rollers 24, 26 are so positioned as to ensure more than tangential contact between each cooling roller 24, 26 and its associated belt. Thus each belt 12, 14 partially wraps around its associated cooling roller 24, 26 to increase the forcible cooling effect achieved thereby to a temperature below the softening point T_g of the toner.

Each belt 12, 14 also passes over a respective second heated roller 28, 30 which heats the belt adjacent the exit 18 of the contact zone Z1 to a temperature at least 10 C° above the softening point T_g of the toner.

A pair of intermediate pressure rollers 32, 34, exert-

ing a pressure of, say, 7.5 N/cm^2, are located one on either side of the extended contact zone Z1, upstream of the cooling rollers 24, 26.

Each belt 12, 14 also passes over a respective tensioning and alignment roller 36, 38, the position of which is adjustable, by operation of means not shown, well known to those skilled in the art, to ensure adequate tension in the belts and to ensure their correct alignment. The unit is driven by the paper web. A drive connected to the second heated roller 28 is driven in torque to compensate for mechanical losses.

The device shown in Figure 1 operates as follows. Substrate in the form of a paper web 40, leaves an electrostatographic printing or copying machine (not shown) carrying unfixed multi-colour toner particle images 42 on both faces. The substrate is fed by a pair of downstream drive rollers 366 along the substrate path between the first and second belts 12, 14 from the entrance 16 to the outlet end 18 of the extended contact zone. The substrate is fed at a speed such as to spend from 5 to 10 seconds in the contact zone. The belts 12, 14 are heated by the heating rollers 20, 22 adjacent the entrance 16 to 160°C, which is above the softening point T_g of the toner. The belts 12, 14 are forcibly cooled by the cooling rollers 24, 26 intermediate the entrance and the exit to 50°C, which is below the softening point T_g of the toner. The toner images 42 on the substrate thereby become fixed to the substrate, and their appearance is rendered glossy, with high colour saturation. The second heated rollers 28, 30 heat the belts to 70°C, to ease the release of the toner from the belt.

In Figure 2, there are shown charts plotting pressure and temperature against the position of the substrate in the device according to Figure 1. Both plots indicate position along their horizontal axes, by using the reference numbers used in Figure 1.

Referring to the chart of Figure 2a, it will be seen that the pressure P to which the substrate is subjected rises as the substrate enters the contact zone, with the heated roller 20 at the entrance thereof. Pressure then falls back to an intermediate value P_c which represents the contact pressure between the first and second belts. Pressure peaks again as the substrate passes between the intermediate pressure rollers 32, 34, with small peaks occurring as the substrate passes the cooling rollers 26 and 24 and the second heated rollers 30 and 28. Thereafter the pressure falls to zero as the substrate leaves the contact zone.

Referring to the chart of Figure 2b, the temperature T of the belt 12 is indicated by a continuous line B. The temperature of the toner on that face of the substrate which is towards the cooling rollers 20, 32, 24 and 28 is indicated by a dotted line F. The temperature of the body of the substrate itself is indicated by a broken line S.

While the substrate is in the contact zone, the temperature of the toner closely follows that of the belt, since it has such a relatively small thermal capacity. It will be seen that the temperature of the toner rises sharply as the substrate enters the contact zone at the entrance of which the first heating rollers 20, 22 are located, the temperature of the toner exceeding the softening temperature T_g thereof. The toner particles are now soft enough to be pressed into the body of the substrate and to be flattened by application of the pressure between the belts leading to the desired fixing and glossing effects. At this high temperature, moisture is driven out of the substrate, but is unable to escape due to the impermeable nature of the belts. The temperature of the body of the substrate rises less rapidly, the toner being located on the surface of the substrate, but gradually heat is transferred from the toner and the belts to the body of the substrate as the substrate progresses through the contact zone. An equilibrium position, where the temperature of the toner and the body of the substrate are identical, may be reached as unforced cooling of both slowly occurs. As the substrate reaches the cooling roller 24, the temperature of the toner, following the temperature of the belt, drops rapidly to a level below T_g, with the temperature of the body of the substrate somewhat lagging behind. This hardens the toner in its fixed and flattened state. This cooling causes the moisture which had been driven out of the substrate to be condensed on the surfaces of the belts, now at a lower temperature than the substrate body. At the exit to the contact zone, where the second heated rollers 30, 28 are located, the temperature of the toner, still following the temperature of the belt, again increases to a level above T_g, with the temperature of the body of the substrate lagging behind.

The temperature difference between the toner and the body of the substrate is important at this point. If the temperature of the body of the substrate were to be above T_g as the substrate separates from the belt 12, there would be a risk of the bond between the toner particles and the substrate breaking, resulting in the deposition of toner on the belt, i.e. resulting in off-set. As it is, the weakest bond is between the toner particles and the belt and it is therefore here that the break occurs, thereby avoiding problems of offset. Furthermore, this second heating drives the moisture which had been condensed on the surfaces of the belts back into the substrate, so that overall substantially no moisture is lost from the substrate.

In the alternative embodiment of Figure 3, the web 50 of a substrate in the form of adhesive labels carried on a plastics material backing web passes over a guide roller 52 before entering the fixing device 54. In this fixing device a single belt 56 passes over a heated roller 58, between a pair of intermediate pressure rollers 60, 62, exerting a pressure of, say, 7.5 N/cm^2, over a second heated roller 64 and a tensioning and alignment roller 66. The belt 56 is impermeable, comprising a 70 µm metal backing carrying a 30 µm coating of non-adhesive silicone material such as DOW200 series (ex Dow Corning Corporation). In this embodiment, the

reaction surface is constituted by the surfaces of two stationary bodies 68, 70, which include passages 72, 74 therethrough for the passage of cooling fluids. The contact of the belt 56 with the stationary bodies 68, 70 defines a contact zone Z2, having an entrance 76 and an exit 78. Downstream of the intermediate pressure rollers 60, 62, there is provided a cooling box 80 which directs cold air against the belt 56 intermediate the entrance and the exit of the contact zone Z2 to cool the belt 56 to a temperature below the softening point T_g of the toner.

The device shown in Figure 3 operates as follows. The substrate leaves an electrostatographic printing or copying machine (not shown) carrying unfixed multi-colour toner particle image 82 on the outer face of the labels. The substrate is fed along the substrate path by a downstream pair of drive rollers 366 from the entrance 76 to the exit 78 of the extended contact zone Z2. The stationary bodies 68,70 are cooled to 90°C and 50°C respectively, while the belt 56 is heated by the heating roller 58 adjacent the entrance 76 to 160°C, which is above the softening point T_g of the toner. The belt 56 is cooled by the cooling box 80 intermediate the entrance and the exit to 50°C, which is below the softening point T_g of the toner. The second heated roller 64 is heated to 70°C. The toner images 82 on the substrate thereby become fixed to the substrate, and their appearance is rendered glossy, with high colour saturation, while no offset on the second heated roller 64 is found. The plastics material backing of the substrate 50 is cooled by passing over the cooling bodies 68, 70, to reduce the possibility of distortion occurring therein. The second heated roller 64 heats the belt 56 to 70°C, to ease the release of the toner from the belt.

Figure 4 shows a single pass, multi-colour duplex electrostatographic printer 510. The printer comprises a first primary seamless belt 512 passing over guide rollers, including a guide roller 514. The primary belt 512 moves in a substantially vertical direction past a set of four toner image producing stations 518, 520, 522, 524. At the four toner image producing stations 518, 520, 522, 524, a plurality of toner images of different colours are transferred by transfer coronas (not shown) to the primary belt 512 in register with each other to form a first multiple toner image.

An intermediate transfer member in the form of an earthed seamless transfer belt 594, is in contact with the primary belt 512 downstream of the last image producing station 524. The intermediate transfer belt is in the form of a metal band of 70 µm thickness carrying a 25 µm thickness silicone rubber coating. The intermediate transfer belt 594 passes over spaced guide rollers 526, 528, 536 and 542 which are so positioned as to bring the transfer belt 594 into contact with the toner image carrying belt 512 as it passes over its upper guide roller 514. The guide roller 542 acts as a first stage heating roller, being formed as a hollow roller through the hollow interior of which a heat transfer fluid such as water at an elevated temperature is passed. The hard metal guide roller 526 acts as a second stage heating roller, being formed for example with an internal radiant heater. The resilient guide roller 528 acts as a cooling roller, being formed with a hollow interior through which cooling fluid, such as water, at a controlled temperature close to room temperature passes.

The heated guide roller 526 is driven by a motor 27. Drive is transmitted in turn from the drive motor 27 to the guide roller 526, via the transfer belt 594 to the primary belt 512 downstream of the toner image producing stations and to the toner image producing stations themselves. The guide roller 514 and the intermediate transfer belt 594 are positioned in opposition to each other to form a contact region therebetween, through which the primary belt 512 passes. Adherent contact between the primary belt and the intermediate transfer belt causes the primary belt and the intermediate transfer belt to move in synchronism with each other.

The multiple toner image adhering to the surface of the primary belt 512 is transferred to the moving intermediate transfer belt 594 by a second function of guide roller 514 acting as an electrostatic transfer roller connected, for example, to -1000 V.

The printer shown in Figure 4 is adapted for duplex printing. To achieve this, the printer further comprises a second primary belt 540 which moves past a second set of four toner image producing stations 519, 521, 523, 525. At the four toner image producing stations 519, 521, 523, 525, a plurality of toner images of different colours are transferred to the primary belt in register with each other to form a second image. A second intermediate transfer belt 596 is in contact with the second primary belt 540 downstream of the last image producing station 525 of the second set.

The second intermediate transfer belt 596 passes over spaced guide rollers including a first stage heating roller 544, a hard metal second stage heating roller 527, a resilient cooling roller 529 and a guide roller 538 which are so positioned as to bring the second transfer belt 596 into contact with the second toner image carrying belt 540 as it passes over its upper guide roller.

The first and second transfer belts 594 and 596 constitute reaction surfaces in face-to-face pressure contact with each other to form an extended contact zone therebetween, thereby to define a substrate path extending through the contact zone from an entrance 516 to an exit 517. Each transfer belt is impermeable, comprising a 70 µm metal backing carrying a 30 µm coating of non-adhesive silicone material such as DOW 200 Series (ex Dow Corning Corporation).

The first transfer belt 594 passes over, and is in contact with, the hard metal heated roller 526 which directly heats the first transfer belt adjacent the entrance 516 to a temperature above the softening point (i.e. the glass transition temperature) T_g of the toner. Similarly, the second transfer belt 596 passes over the heated roller 527 which directly heats the second transfer belt

596 adjacent the entrance 516 to a temperature above the glass transition temperature T_g of the toner.

Each transfer belt 594, 596 also passes over, and is in contact with, the respective resilient cooling roller 528, 529 which directly cools the respective transfer belt intermediate the entrance and the exit of the contact zone to a temperature below the glass transition temperature T_g of the toner. The cooling rollers 528, 529 are so positioned as to ensure more than tangential contact between each cooling roller 528, 529 and its associated transfer belt. Thus each transfer belt 594, 596 partially wraps around its associated cooling roller 528, 529 to increase the forcible cooling effect achieved thereby to a temperature below the glass transition temperature T_g of the toner.

Each transfer belt 594, 596 also passes over a respective second heated roller 530, 531 which heats the transfer belt adjacent the exit 517 of the contact zone to a temperature at least 10 C° above the glass transition temperature T_g of the toner.

A pair of intermediate pressure rollers 532, 534 are located one on either side of the extended contact zone, upstream of the cooling rollers 528, 529, exerting a pressure of, say, 7.5 N/cm^2.

The device shown in Figure 4 operates as follows. Substrate in the form of a paper web 541, unwound from a supply roll 430 is fed by a pair of downstream web drive rollers 366 along the substrate path between the first and second transfer belts 594, 596 from the entrance 516 to the exit 517 of the extended contact zone. Tension in the web 541 is controlled by the application of a brake (not shown). The substrate is fed at a speed such as to spend from 2 to 10 seconds in the contact zone. In a typical embodiment, the first-stage heating rollers 542, 544 raise the temperature of the multi-colour toner image on the transfer belts 594, 596 to about 90°C. The transfer belts 594, 596 are then heated by the heating rollers 526, 527 adjacent the entrance 516 to 160°C, which is above the glass transition temperature T_g of the toner and is the optimum temperature for final transfer to the paper web 541. The transfer belts 594, 596 are forcibly cooled by the cooling rollers 528, 529 intermediate the entrance and the exit to 50°C, which is below the glass transition temperature T_g of the toner. The toner images on the transfer belts 594, 596 are transferred to the substrate and become fixed to the substrate, and their appearance is rendered glossy, with high colour saturation. The second heated rollers 530, 531 heat the belts to 70°C, to ease the release of the toner from the belts. Following transfer of the images to the substrate 541 the cooling rollers 536, 538 reduce the temperature of the transfer belts to about 20°C, ideal for electrostatic transfer of a further image onto the transfer belts.

Downstream of the drive roller pair 366, the paper web passes to a cutting station 466 where the web is cut into sheets.

The present invention provides a number of advantages compared with known devices:

(i) the consumption of toner powder may be reduced;
(ii) the moisture content of the substrate is retained;
(iii) where the substrate is a transparent material, such as an over-head projector sheet, the contrast of the image is improved;
(iv) gloss can be deeper than can be achieved with known devices, because the first roller can be very hot;
(v) there are no additional consumables; and
(vi) better coverage of the substrate by the toner particles leads to the possibility of a greater range of hues obtainable from combinations of toners of different colours, since the colour of the substrate itself plays a less important role to the spectral character of the image.

Claims

1. A device for fixing an unfixed toner particle image on a substrate, comprising an endless surface (12; 56; 594), a reaction surface (14; 68, 70; 596) in face-to-face pressure contact with said endless surface (12; 56; 594) to form a contact zone (Z1; Z2) therebetween, extending continuously from an entrance (16; 76; 516) to an exit (18; 78; 517), means (366) for feeding a substrate (40; 50; 541) through said contact zone from said entrance to said exit, heating means (20; 58; 526) for heating said endless surface (12; 56; 594) adjacent said entrance (16; 76; 516) to a temperature above the softening point T_g of the toner, and cooling means (24; 80; 528) for forcibly cooling said endless surface (12; 56; 594) intermediate said entrance (16; 76; 516) and said exit (18; 78; 517) to a temperature below the softening point T_g of said toner characterised by means (32, 34; 60, 62; 532, 534) for applying pressure between said endless surface (12; 56; 594) and said reaction surface (14; 68, 70; 596) intermediate the entrance and exit.

2. A device according to claim 1, further including second heating means (28; 64; 530) for heating said endless surface (12; 56; 594) adjacent said exit (18; 78; 517) to a temperature above the softening point T_g of said toner.

3. A device for fixing an unfixed toner particle image on a substrate, comprising an endless surface (12; 56; 594), a reaction surface (14; 68, 70; 596) in face-to-face pressure contact with said endless surface (12; 56; 594) to form a contact zone (Z1; Z2) therebetween, extending continuously from an entrance (16; 76; 516) to an exit (18; 78; 517), means (366) for feeding a substrate (40; 50; 541) through said contact zone from said entrance to

said exit, heating means (20; 58; 526) for heating said endless surface (12; 56; 594) adjacent said entrance (16; 76; 516) to a temperature above the softening point T_g of the toner, and cooling means (24; 80; 528) for forcibly cooling said endless surface (12; 56; 594) intermediate said entrance (16; 76; 516) and said exit (18; 78; 517) to a temperature below the softening point T_g of said toner characterised by second heating means (28; 64; 530) for heating said endless surface (12; 56; 594) adjacent said exit (18; 78; 517) to a temperature above the softening point T_g of said toner.

4. A device according to claim 1, 2 or 3, wherein both said endless surface (12; 56; 594) and said reaction surface (14; 68, 70; 596) are impermeable.

5. A device according to claim 1, wherein said cooling means (24; 528) is constituted by a cooling roller so positioned as to ensure more than tangential contact between the cooling roller and the endless surface (12; 594).

6. A device according to any preceding claim, wherein said reaction surface is constituted by a further endless surface (14; 596) and wherein said further endless surface is provided with further heating means (22; 527) for heating said further endless surface (14; 596) adjacent said entrance (16; 516) to a temperature above the softening point T_g of the toner, and further cooling means (26; 529) for forcibly cooling said further endless surface (14; 596) intermediate said entrance (16; 516) and said exit (18; 517) to a temperature below the softening point T_g of said toner.

7. A single pass, electrostatographic printer comprising:

- a transfer member (594);
- drive means (27) for moving said transfer member (594) along a continuous path;
- deposition means (512) for depositing a toner image in powder form on said transfer member (594) to form an unfixed toner particle image thereon; and
- a reaction surface (596) in face-to-face pressure contact with said transfer member (594) to form a contact zone therebetween, extending continuously from an entrance (516) to an exit (517),
- means (366) for feeding a substrate (541) through said contact zone from said entrance (516) to said exit (517), whereby said toner image is transferred to said substrate;
- heating means (526) for heating said transfer member (594) adjacent said entrance (516) to a temperature above the softening point T_g of the toner, and
- cooling means (528) for forcibly cooling said transfer member (594) intermediate said entrance (516) and said exit (517) to a temperature below the softening point T_g of said toner.

8. A method of fixing an unfixed toner particle image (42; 82; 500) on a substrate, comprising:

- feeding said substrate (40; 50; 541) through a contact zone (Z1; Z2) which extends continuously from an entrance (16; 76; 516) to an exit (18; 78; 517) thereof and is defined by an endless surface (12; 56; 594) and a reaction surface (14; 68, 70; 596) in face-to-face pressure contact with said endless surface (12; 56; 594);
- heating said endless surface (12; 56; 594) adjacent said entrance (16; 76; 516) to a temperature above the softening point T_g of the toner; and
- forcibly cooling said endless surface (12; 56; 594) intermediate said entrance (16; 76; 516) and said exit (18; 78; 517) to a temperature below the softening point T_g of said toner, characterised by applying pressure between said endless surface (12; 56; 594) and said reaction surface (14; 68, 70; 596) intermediate said entrance (16; 76; 516) and said exit (18; 78; 517).

9. A method of fixing an unfixed toner particle image (42; 82; 500) on a substrate (40; 50; 541), comprising:

- feeding said substrate (40; 50; 541) through a contact zone (Z1; Z2) which extends continuously from an entrance (16; 76; 516) to an exit (18; 78; 517) thereof and is defined by an endless surface (12; 56; 594) and a reaction surface (14; 68, 70; 596) in face-to-face pressure contact with said endless surface (12; 56; 594);
- heating said endless surface (12; 56; 594) adjacent said entrance (16; 76; 516) to a temperature above the softening point T_g of the toner; and
- forcibly cooling said endless surface (12; 56; 594) intermediate said entrance (16; 76; 516) and said exit (18; 78; 517) to a temperature below the softening point T_g of said toner, characterised by heating said endless surface (12; 56; 594) adjacent said exit (18; 78; 517) of said extended contact zone (Z1; Z2) to a temperature above the softening point T_g of said toner.

10. A method according to claim 8 or 9, wherein said endless surface means (12; 56; 594) contacts said substrate (40; 50; 541) with a dry surface.

11. A method according to claim 8, 9 or 10, wherein said unfixed toner particle image (42; 82) is already present on said substrate (40; 50) prior to feeding said substrate (40; 50) through said contact zone.

12. A method according to claim 8, 9 or 10, wherein said unfixed toner particle image (500) is carried on said endless surface (594) to be transferred to said substrate (541) in said contact zone.

13. A method of single pass, electrostatographic printing comprising:

- moving a transfer member (594) along a continuous path;
- depositing a toner image in powder form onto said moving transfer member (594) to form an unfixed toner particle image (500) thereon;
- feeding substrate (541) through a contact zone which extends continuously from an entrance (516) to an exit (517) thereof and is defined by said moving transfer member (594) carrying said unfixed toner particle image (500) and a reaction surface (596) in face-to-face pressure contact with said moving transfer member (594) whereby said toner image (500) is transferred to said substrate (541);
- heating said transfer member (594) adjacent said entrance (516) to a temperature sufficient to reduce the viscosity thereof to less than 50 Pa s (such as 10 to 40 Pa s); and
- forcibly cooling said transfer member (594) intermediate said entrance (516) and said exit (517) to a temperature below the softening point T_g of said toner.

14. A method according to claim 13, including depositing a plurality of toner images of different colours in powder form in register with each other onto said moving transfer member (594) to form a multiple toner image (500) thereon.

15. A method for the transfer of a toner image (500) in powder form from a transfer member (594) to a substrate (541), comprising:

(1) heating said toner image (500) to a temperature sufficient to reduce the viscosity thereof to less than 50 Pa s;
(2) bringing said transfer member (594) carrying said toner image (500) into contact with said substrate (541);
(3) forcibly cooling said transfer member (594) to a temperature below the glass transition temperature T_g of the toner while said transfer member (594) remains in contact with said substrate (541); and
(4) thereafter separating said transfer member (594) from said substrate (541).

16. The method of claim 15, wherein said toner image (500) is formed of toner having a composition comprising a thermoplastic binder and from 10% to 50% by weight, based on the weight of the toner composition, of a pigment.

17. The method of claim 15, wherein said toner image (500) is formed of a toner composition in powder form, having a weight average particle size of between 0.5 µm and 5 µm.

18. The method of claim 15, wherein said multiple toner image (500) is heated to a temperature of more than the glass transition temperature T_g, but below the degradation temperature of said toner.

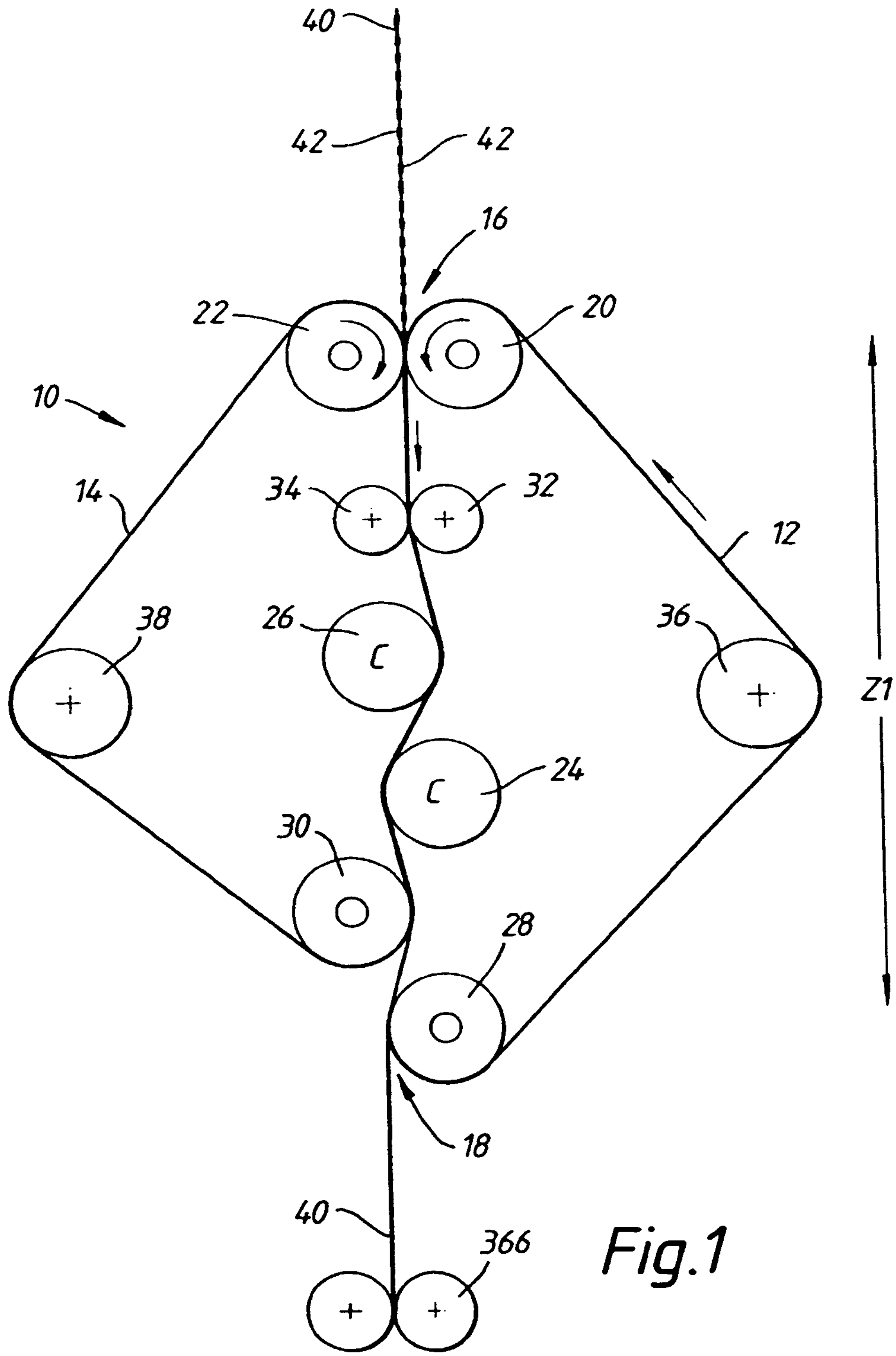
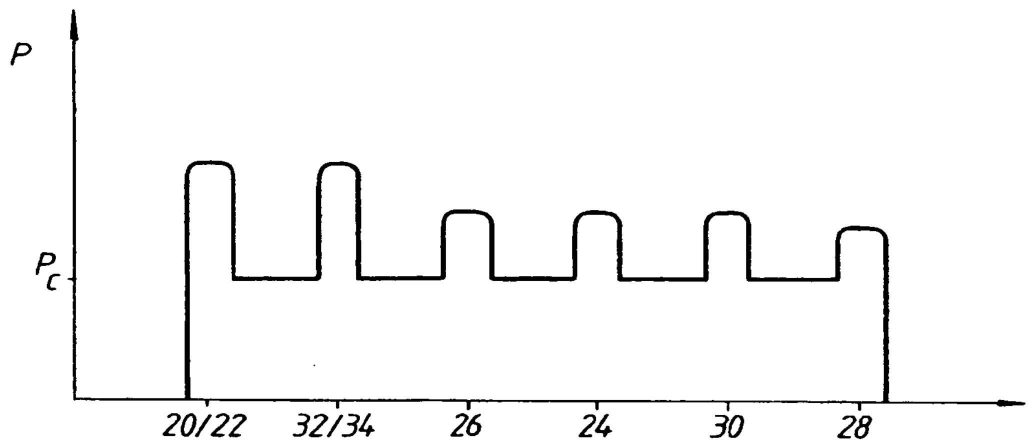


Fig.1


P
P_c
20/22
32/34
26
24
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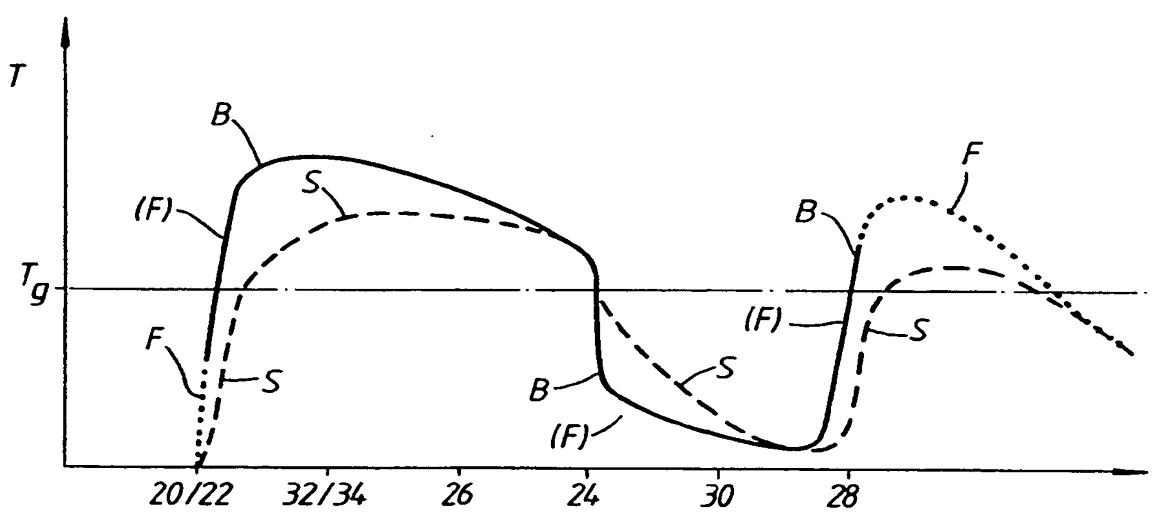
28

Fig. 2a


T
T_g
B
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(F)
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Fig. 2b

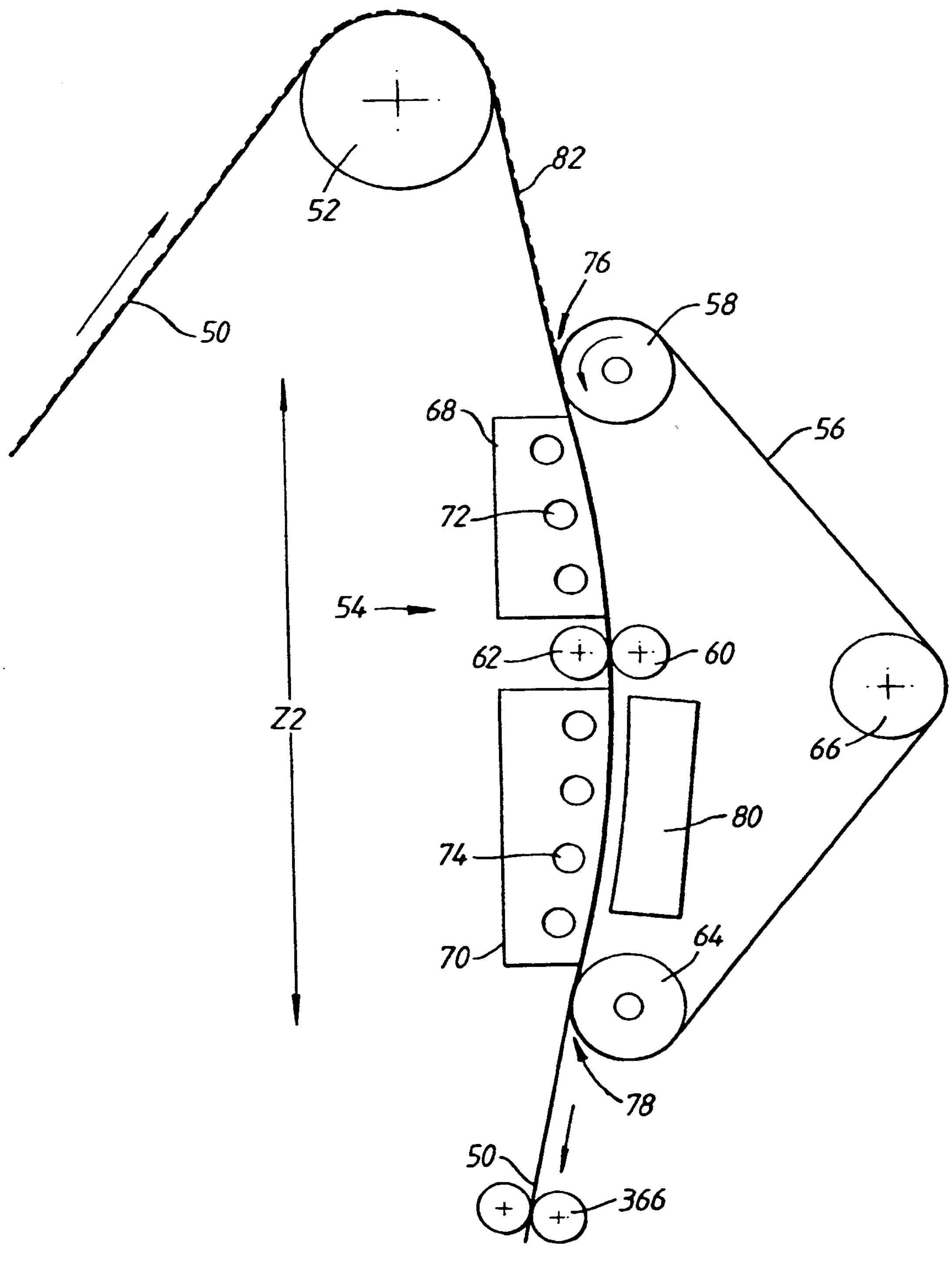
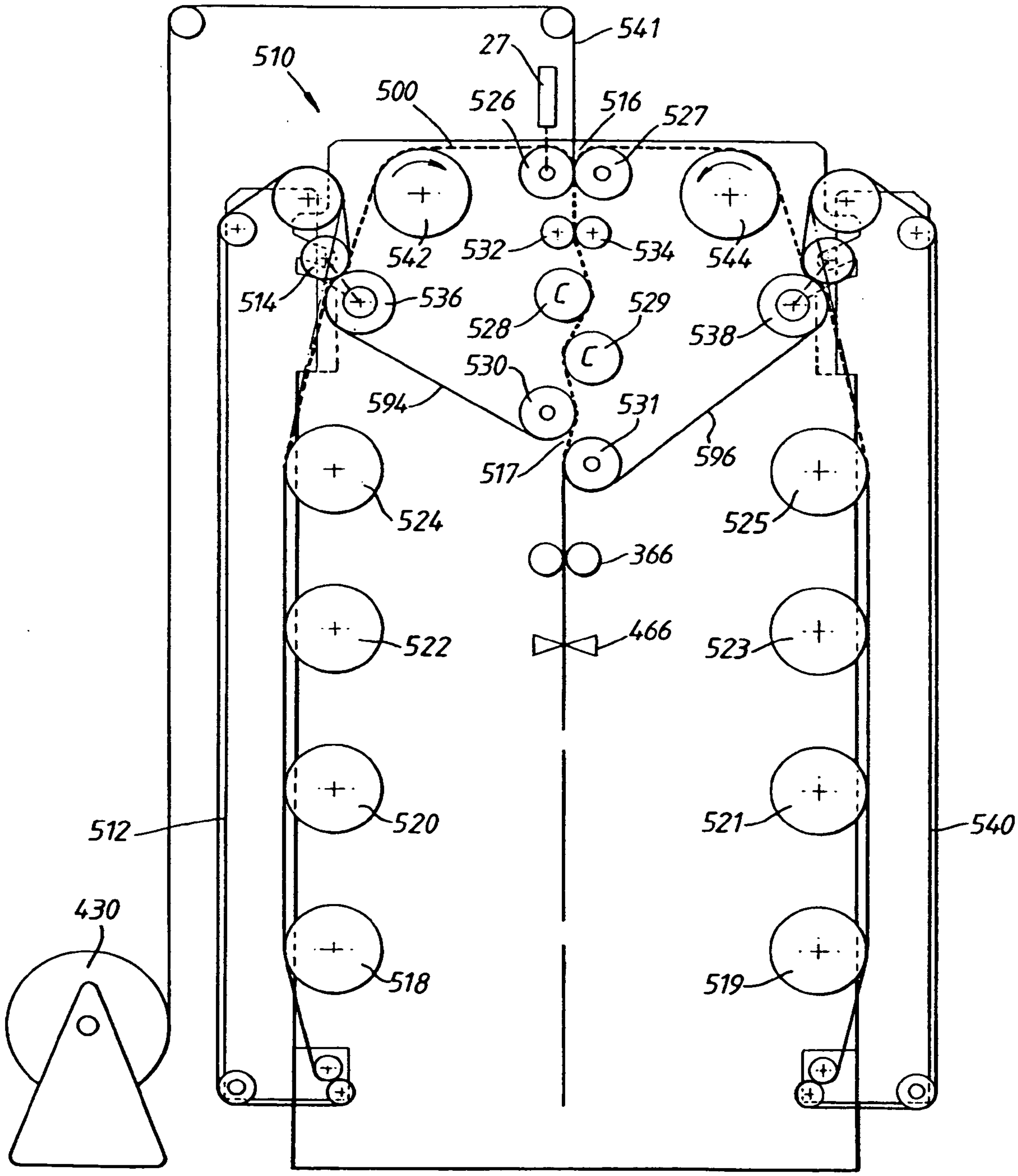


Fig.3


541
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430
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519

Fig.4

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(54) Device and method for fixing and glossing toner images

(57) The device for fixing an unfixed toner particle image (42) on a substrate (40) comprises a belt (12) in face-to-face contact with a reaction surface such as a further belt (14) to form an extended contact zone (Z1) therebetween, to define a substrate path extending through the contact zone (Z1) from an entrance (16) to an exit (18). Heating means (20) heat the belt (12) adjacent the entrance (16) to a temperature above the softening point T_g of the toner. Cooling means (24) forcibly cool the belt (12) intermediate the entrance (16) and the exit (18) to a temperature below the softening point T_g of the toner. Means (32, 34) are provided for applying pressure between the belts (12, 14) intermediate the entrance and exit. Second heating means (28) heat the belt (12) adjacent the exit (18) to a temperature above the softening point T_g of said toner. Thereby un-fixed toner images formed on the substrate can be fixed thereto and provided with a desirable level of gloss in one single device.

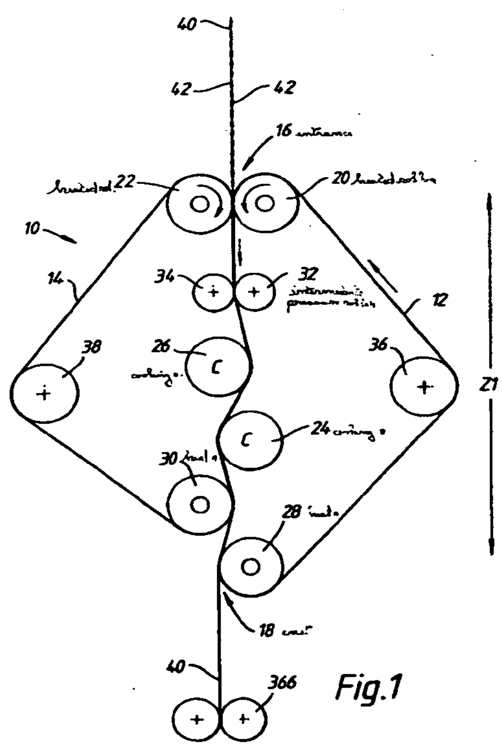

Fig.1

EP 0 848 304 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 97 30 8324

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,A	US 5 319 429 A (FUKUCHI MASAKAZU ET AL) 7 June 1994 * column 11, line 33 - column 14, line 9; figures 6-17 *	1,6,7,9	G03G15/20 G03G15/16
A	WO 91 03773 A (EASTMAN KODAK CO) 21 March 1991 * page 10, line 29 - page 12, line 9; figures 1-4 *	1,7	
A	PATENT ABSTRACTS OF JAPAN vol. 017, no. 573 (P-1630), 19 October 1993 -& JP 05 165350 A (KONICA CORP), 2 July 1993 * abstract *	1,7	
D,A	US 3 948 215 A (NAMIKI RYOICHI) 6 April 1976 * column 6, line 9 - line 57; figures 5,6 *	1,5,7	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
G03G

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 August 1998	CIGOJ, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

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European Patent
Office

Application Number
EP 97 30 8324

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1, 2, 5, 8, and 4, 6 as far as depending on 1 or 2, and 10, 11, 12 as far as depending on 8

European Patent Office

LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 97 30 8324

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1, 2, 5, 8 and 4, 6 as far as depending on 1 or 2, and 10, 11, 12 as far as depending on 8

   Fixing by passing an unfixed toner image in a heated and then cooled contact zone with application of pressure intermediate the entrance and exit of said zone

2. Claims: 3, 9 and 4, 6 as far as depending on 3, and 10, 11, 12 as far as depending on 9

   Fixing by passing an unfixed toner image in a heated and then cooled contact zone with second heating adjacent the exit of the contact zone

3. Claims: 7, 13 to 18

   Transfer of a toner image to a substrate by feeding said substrate in a contact zone heated adjacent its entrance to reduce the toner viscosity and then cooled below the toner softening point